AIMS Program

Microturbine & Industrial Gas Turbine Peer Review Meeting

March 12-14, 2002
Hyatt Fair Lakes
Fairfax, VA

Program Overview

OBJECTIVE

The objective of the AIMS program is to develop the next generation microturbine system that will advance the current generation system into a more efficient, cost effective, and environmentally friendly system. The resulting system will be designed such that it addresses both the current and emerging distributed generation markets.

CTQ'S

- 40% Efficient Design
- 175 kW Output with growth to +250 kW
- ≤ 10 ppm NOx on Natural Gas
- ≤ 10 ppm CO on Natural Gas
- ≤ $500/kW unit cost
- 11,000 hour maintenance interval
- 45,000 hour life

SCHEDULE Milestones/Deliverables	Scheduled Completion Date	Status (complete, in progress, planned, ...)
• Subtask A – Market Study	12-31-00	Complete
• Task 1 – Conceptual Design	4-1-01	Complete
• Subtask B – Business Plan	12-31-02	Planned
• Task 2 – Component Design	7-1-03	In Progress
• Task 3 – System Design	7-1-03	In Progress
• Task 4 – Laboratory Evaluation	12-31-03	Planned
• Task 5 – Demonstration	9-29-04	Planned

PROFILE BUDGETS

Planned Total $ 4.7M + Cost Share
Project Start/End 10/00 - 9/04

PROJECT TEAM

GE Global Research
GE Power Systems (GEPS)
GE Industrial Systems (GEIS)
Concepts NREC
Turbo Genset Company
Kyocera Industrial Ceramics Corp.
Onsite Energy Corporation
Oak Ridge National Laboratory

PROJECT STATUS - Red/Yellow/Green

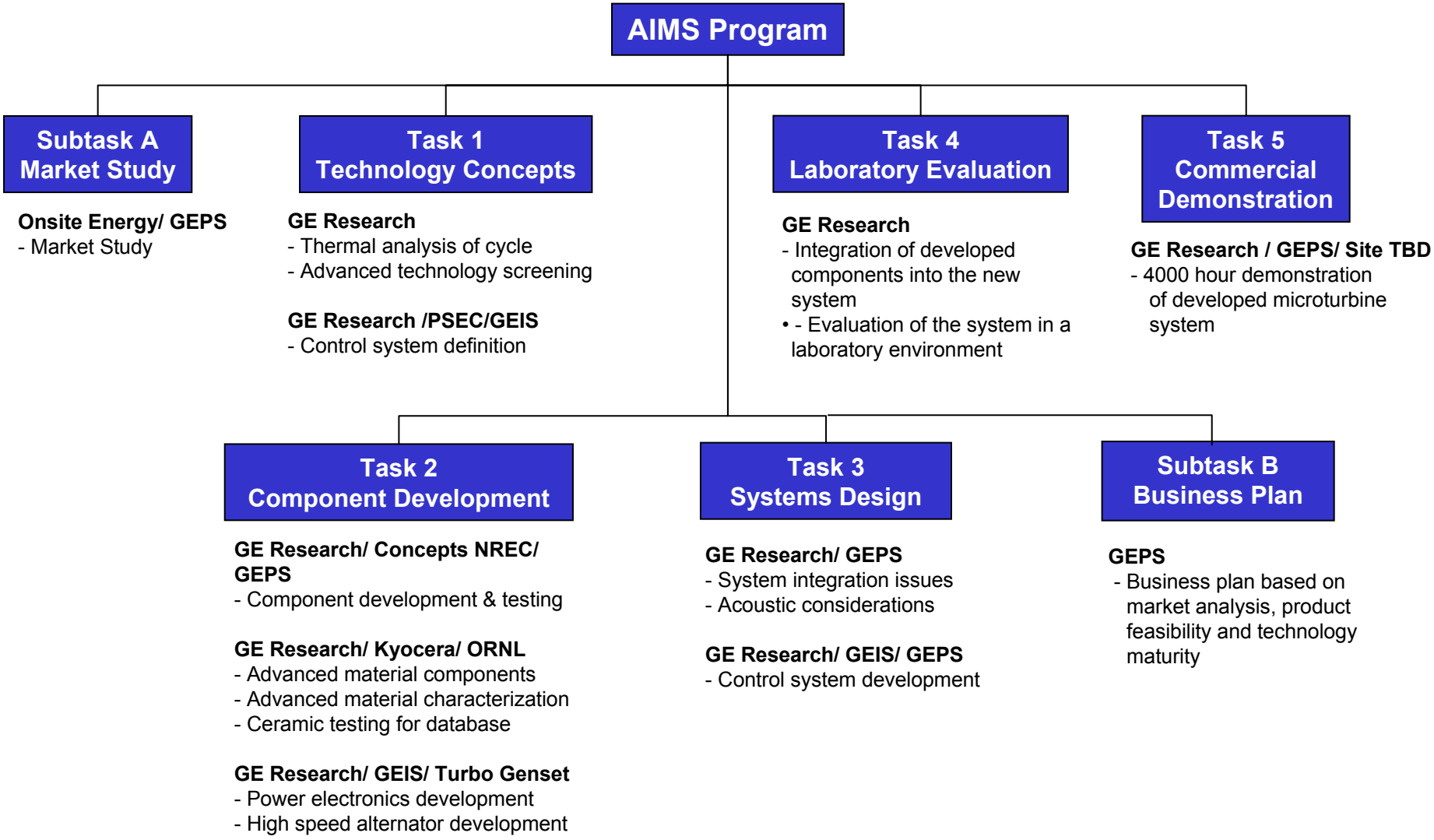
Yellow
Status

- Many tasks dependent on Vendors
- Budgetary concerns

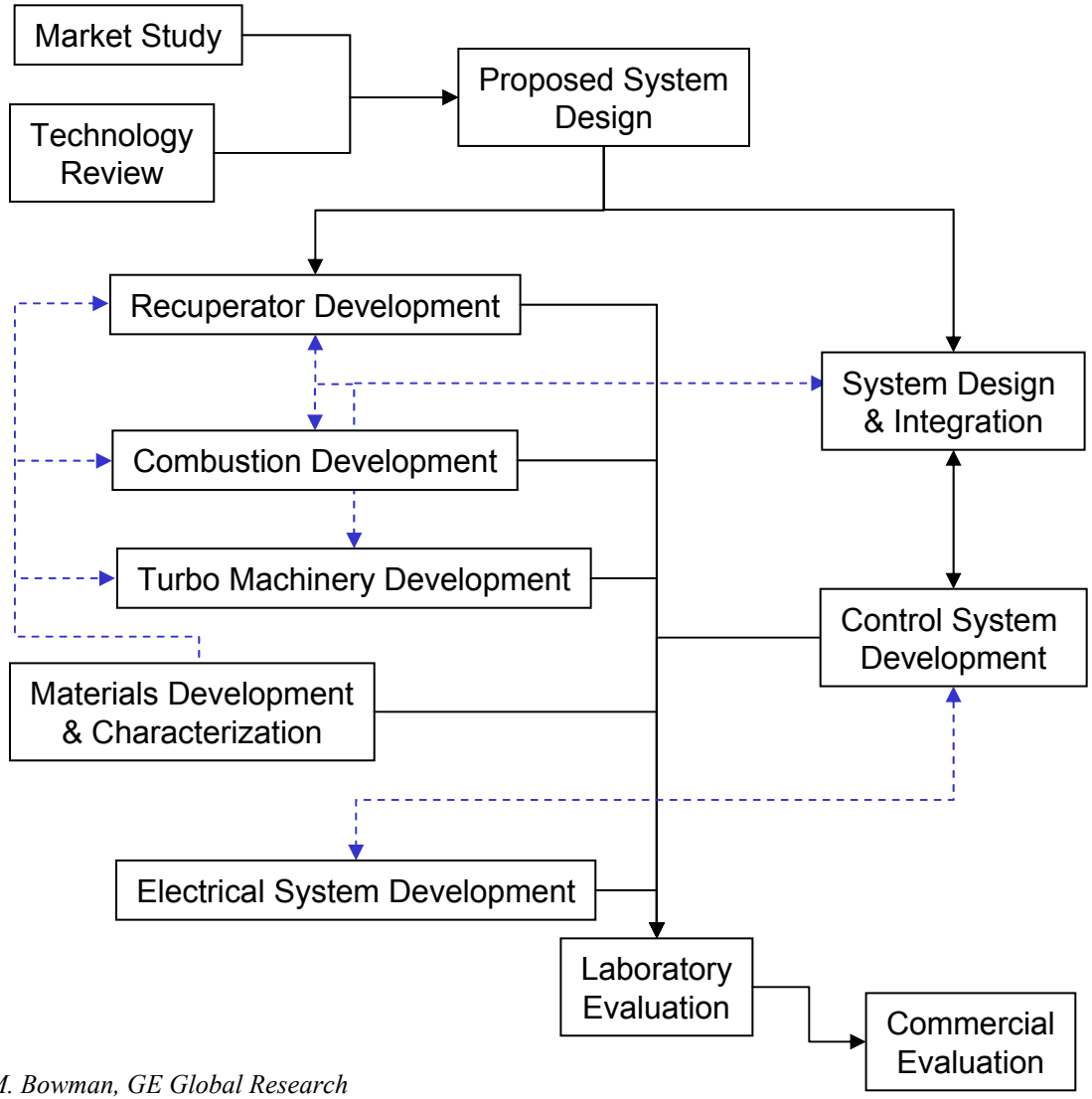
PATENTS/PAPERS

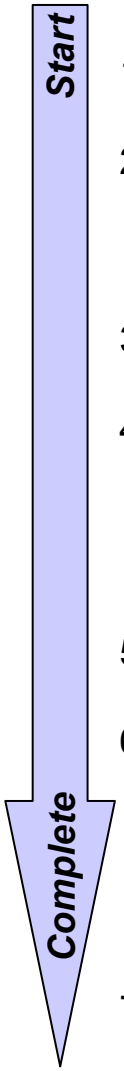
- 1 ASME Papers to be presented in June
- Over 20 Patent Disclosures Filed

Program Team



AIMS Program Matrix & Milestones





Major Milestones

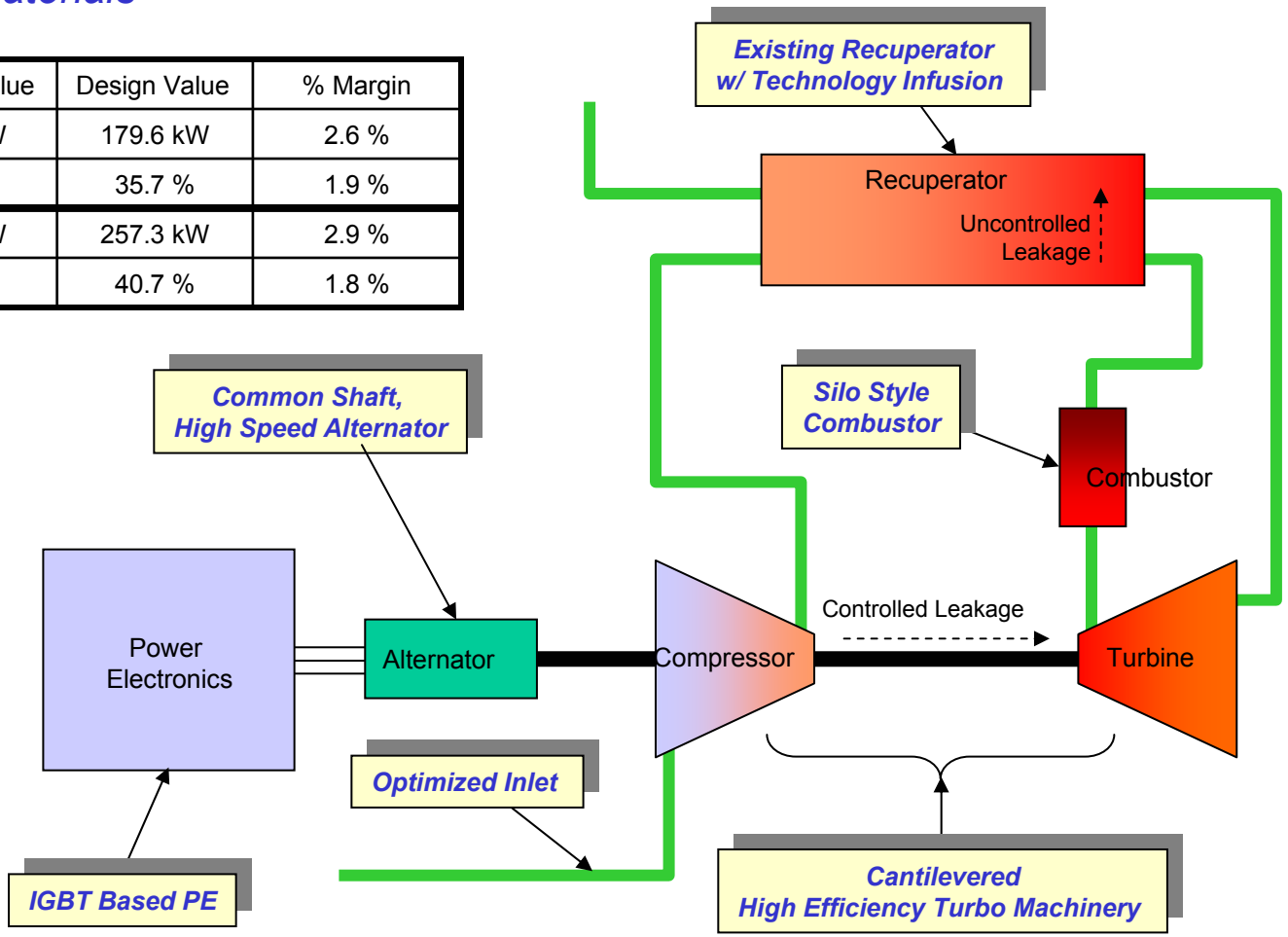
1. Market Study Complete
2. Thermal Design Complete
3. Metallic Unit Ready for Test
4. Lab Evaluation of Metallic Unit Complete
5. Advanced Unit Ready for Test
6. Lab Evaluation of Advanced Unit Complete
7. Commercial Demo

Task – Conceptual Design

TASK FOCUS:

- Determine system thermal design to achieve the 40% efficiency target
- Reduce the operating temperature of the cycle to "metallic" levels
  - ➥ *this process allows for proof of component technologies prior to the introduction of advanced materials*

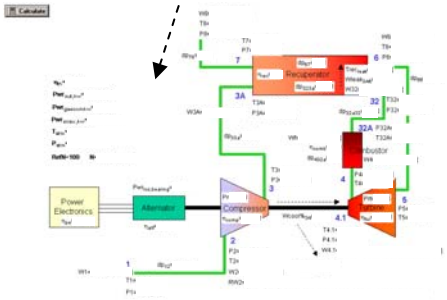
	Target Value	Design Value	% Margin
Cycle Output	175 kW	179.6 kW	2.6 %
Cycle Efficiency	35 %	35.7 %	1.9 %
Cycle Output	250 kW	257.3 kW	2.9 %
Cycle Efficiency	40 %	40.7 %	1.8 %



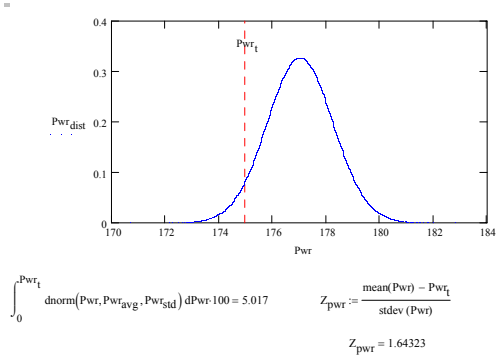
Task – Design Process

PROCESS:

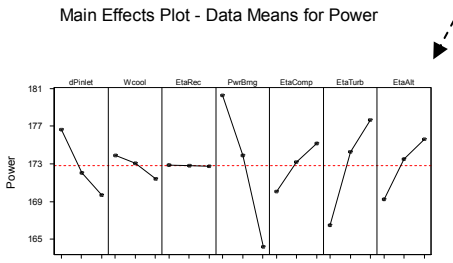
Step 1: Build parametric performance model for the AIMS microturbine



Step 2: Conduct trade study to determine key microturbine performance parameters



Step 3: Perform full factorial DOE on key parameters and create a transfer function



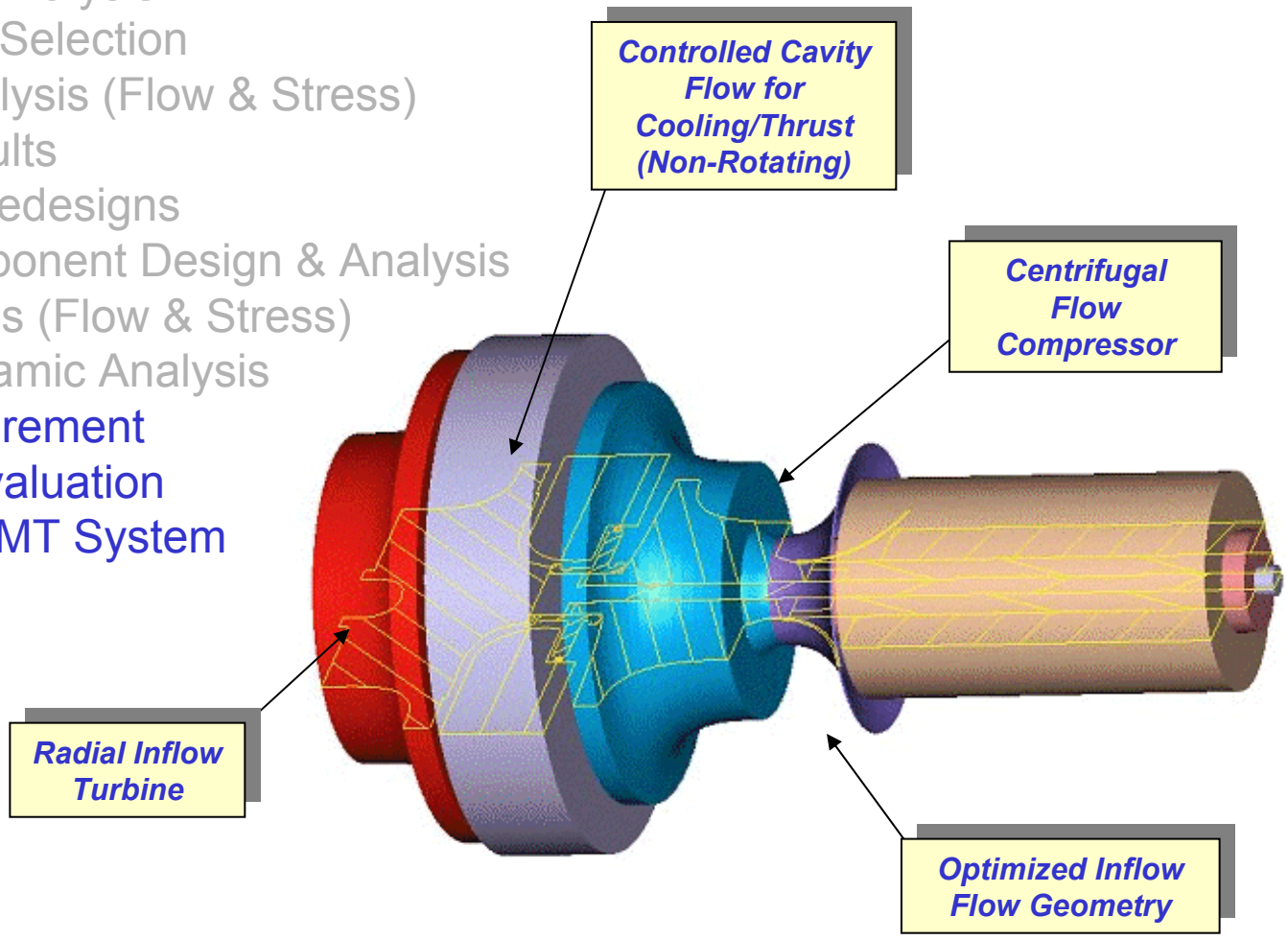
Step 4: Run a simulation using random normal data as inputs to the transfer functions

Step 5: Determine the required input distributions of the key parameters so to achieve the desired outputs of power and efficiency

Task – Turbo Machinery

ACTIVITIES:

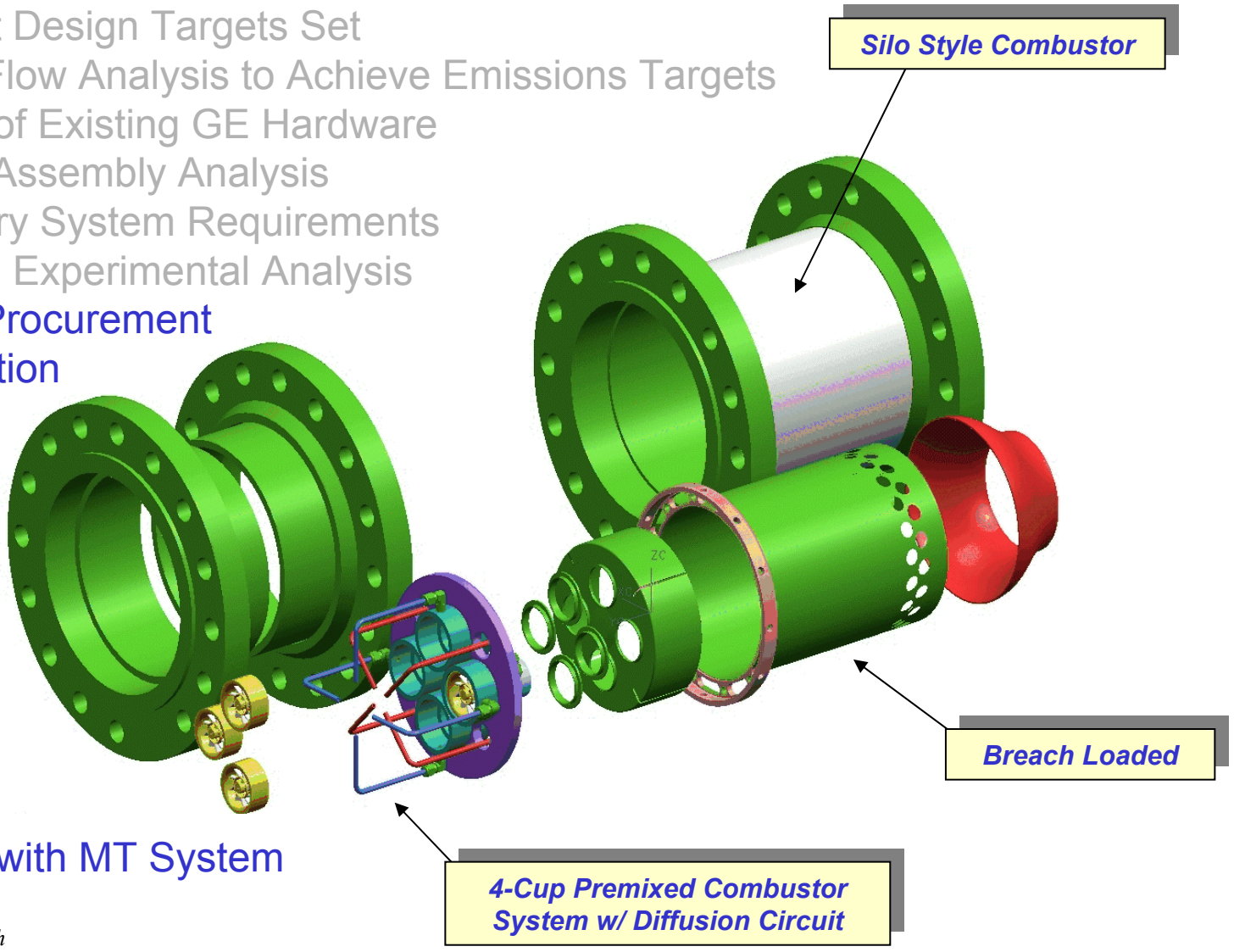
- Component Design Targets Set
- 1D Analysis (Flow & Stress)
- Rotor Dynamic Analysis
- Materials Down Selection
- 1st Pass 3D Analysis (Flow & Stress)
- Analysis of Results
- Modifications/ Redesigns
- Stationary Component Design & Analysis
- Final 3D Analysis (Flow & Stress)
- Final Rotor Dynamic Analysis
- Hardware Procurement
- Experimental Evaluation
- Integration with MT System
- Evaluation



Task - Combustion

ACTIVITIES:

- Component Design Targets Set
- Fuel & Air Flow Analysis to Achieve Emissions Targets
- Evaluation of Existing GE Hardware
- Thermal & Assembly Analysis
- Fuel Delivery System Requirements
- "Similar To" Experimental Analysis
- Hardware Procurement
- Lab Evaluation
- Integration with MT System
- Evaluation



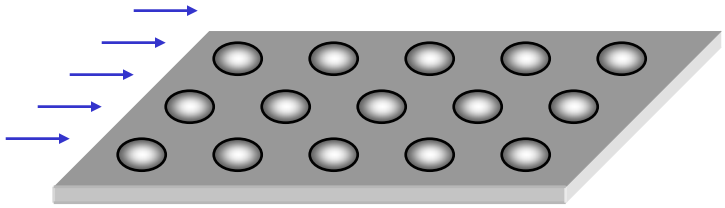
Task - Recuperator

TASK FOCUS:

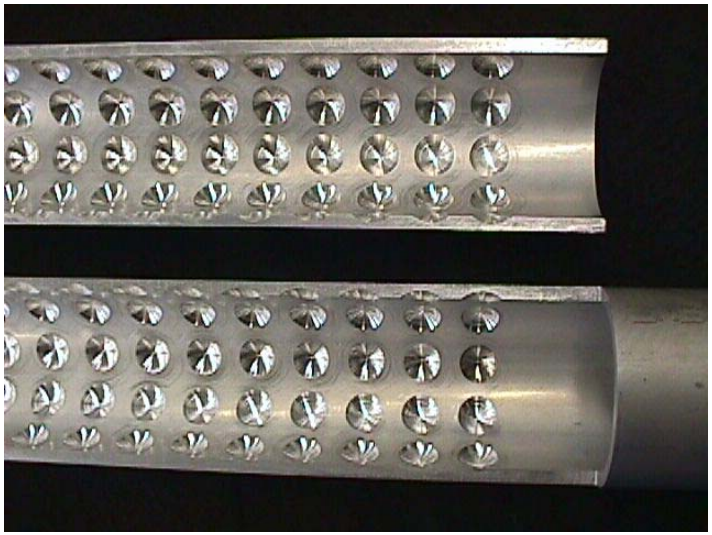
Infuse GE expertise of gas turbine heat transfer into existing recuperator technology to build a better system.

ACTIVITIES:

- Performance Design Targets Set
- Reverse Engineered Existing Recuperator – Validated with Experiments
- Preliminary Sizing of Recuperator
- Potential Heat Transfer Enhancement Technologies Identified
- Design Impact of Technologies Determined
- Capable Vendors Identified
- Vendor Finalized
- Initial Hardware Procurement
- New Technology Design Incorporation
- New Technology Sample Procurement
- New Technology Sample Experimental Evaluation
- New Technology Prototype Procurement
- Experimental Evaluation



Task - Recuperator



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- Tube 3: Depth = 0.16", Spacing = 0.523"
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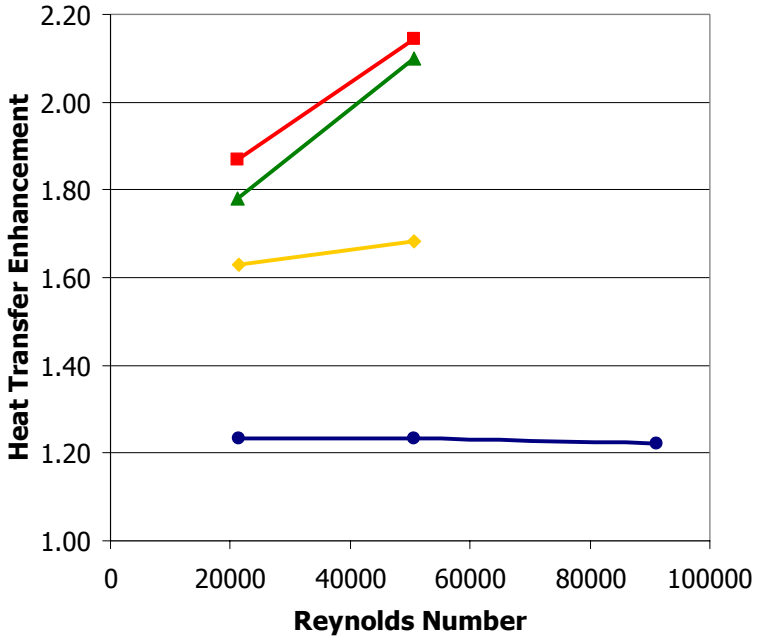
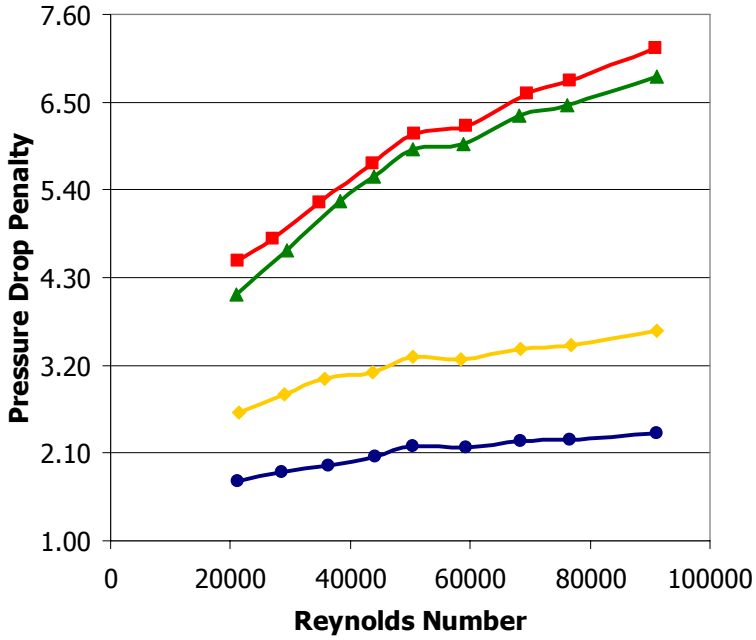
Dimple Diameter =0.39”

Tube Diameter = 1.50”





M. Bowman, GE Global Research

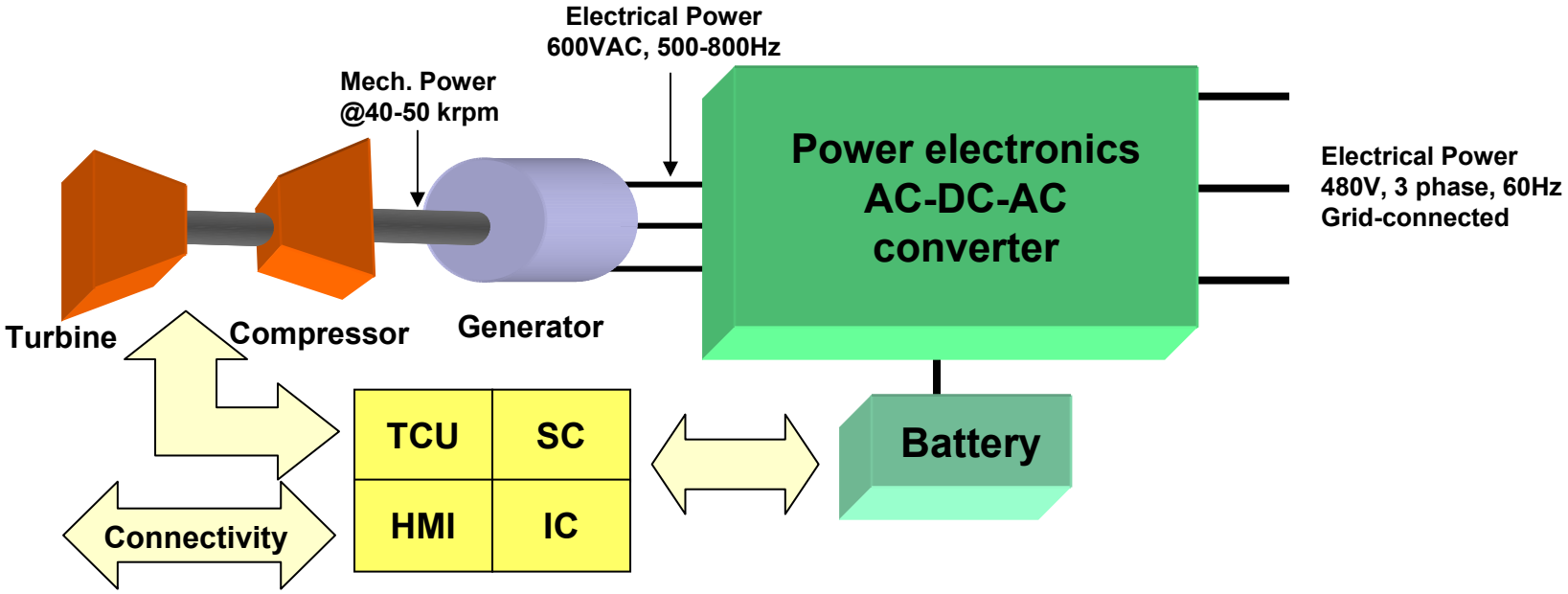
Task – Power Electronics & Control

PE ACTIVITIES:

- Specifications & Topology Tradeoffs
- Generator Vendor Selection
- Power Electronic Simulations
- Auxiliary System Design
- FMEA
- Component Fabrication
- System Tests
- Integration w/ Turbine System

CONTROLS ACTIVITIES:

- Control Requirements
- System Simulations
- Platform Selection
- Algorithm & Code Development
- Communication & HMI Development
- Hardware Procurement
- Integration w/ Turbine System



Task – Advanced Materials

Program Activities for Ceramic Components in AIMS Microturbine

TECHNOLOGY CHALLENGES:

- Temperature: 1100+°C
- Strength degradation
- Surface recession due to water vapor
- Impact FOD damage
- Probabilistic life and reliability
- Attachments
- Shrinking number of suppliers
- Complex shapes
- Cost

Courtesy Kyocera

Microturbine design for best use of ceramics
- Select components for highest payoff and lowest risk
- Combustor, scroll, nozzle, rotor, recuperator

Ceramic property database for chosen materials
- Concentrate on silicon nitrides
- Supplement ORNL database

Probabilistic design capability for ceramic component
- NASA CARES/LIFE
- Honeywell CERAMIC/ERICA
- GE extensions

Demonstration of ceramic component
- Fabricate prototype parts
- Test in baseline microturbine

Incorporation of ceramic components requires innovative ceramic application engineering

Task – Advanced Materials

MATERIAL DATABASE AND TEST PLAN:

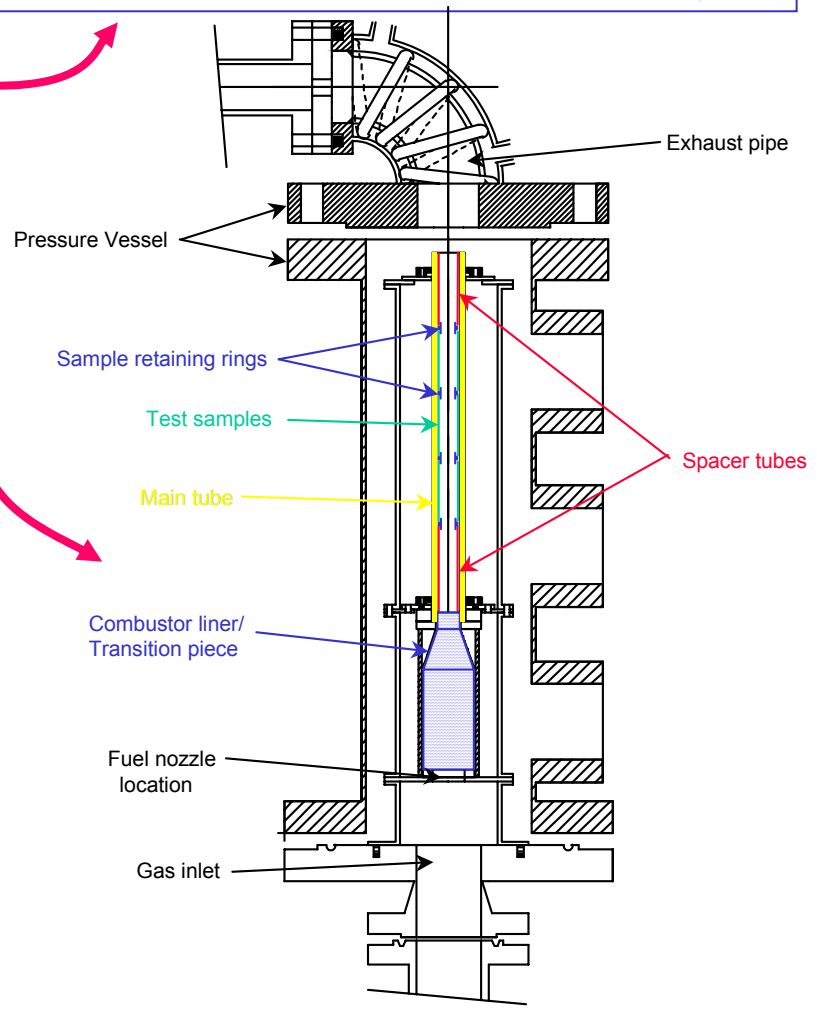
Currently concentrating on Kyocera SN282
Limited design data currently available
GE testing in collaboration with ORNL
Prioritized needs for database expansion

- **Tensile fast fracture**
- Strength degradation after oxidation
- **Surface recession and strength degradation in moist environments**

Silicon nitride obtained for first round of testing
Initial specimens in preparation

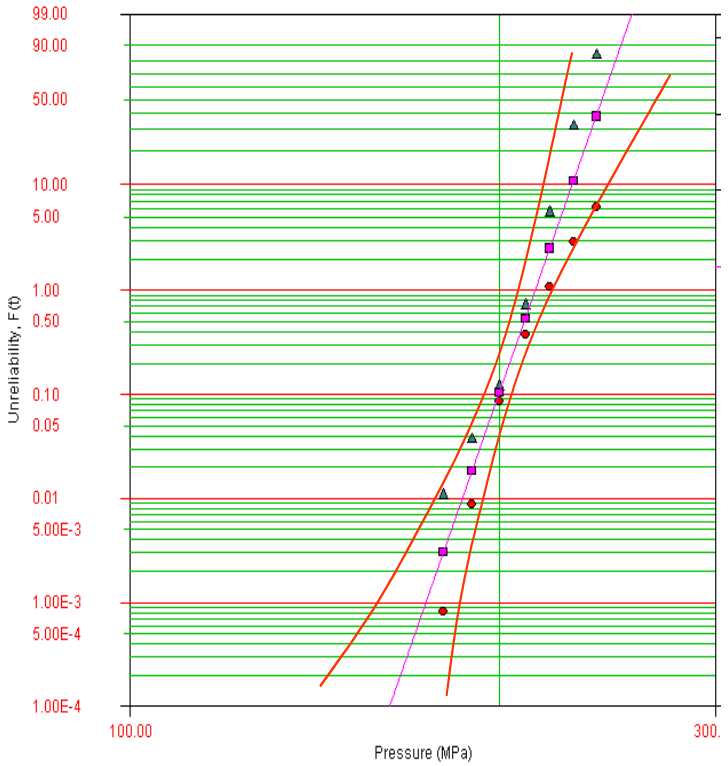
Fast Fracture Tensile Testing
- Room and elevated temperatures
- Testing at ORNL
- Fractography for censored data analysis
- "Large" specimen size to reduce confidence bounds on predicted component reliability

Exposure tests in high pressure/ high velocity burner rig
- Rig at GE Global Research
- Developed for GE/DOE CMC program
- Capable of exposures at:
  - 1200 °C
  - 125 m/s
  - 9 atmospheres total pressure
  - 1 atmosphere of water vapor
- Post test evaluation:
  - Surface recession rate
  - Strength degradation (flexure)
- Test planning in progress



Task – Advanced Materials

Build on CARES/LIFE Capability for Probabilistic Design



CURRENT CARES/LIFE CAPABILITIES:

- Weibull probabilistic analysis in multiaxial stress states
- Estimation of Weibull and fatigue parameters
- Confidence bounds on single flaw populations
- Censored data analysis for multimodal flaw populations
- Integration with component finite element analysis
- Prediction of component life and probability of failure

GE ADDITIONS:

Parameter estimation for pooled data

- Weibull parameters
- Censored data for multimodal flaw populations

Confidence intervals with censored data

- Weibull parameters
- Component fast fracture reliability

Code to execute and integrate with CARES/LIFE

Improved probabilistic capability for ceramic design

Summary

PROGRAM:

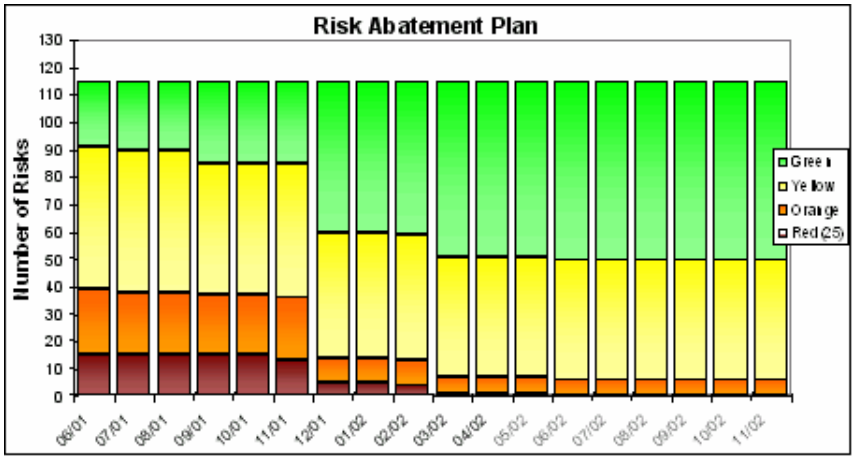
- Team has made significant progress in all areas
- Design is nearly complete
- Moving into procurement phase
- Preparing for experimental evaluation of the technology

TOP RISKS:

- Demonstration Milestones Dependent on Vendor Deliveries
- Program funding limits result in schedule delay
- Component Performance Shortfall

ABATEMENTS:

- Extensive Vendor evaluations
- Close and consistent contact with Venders
- Close monitoring & prioritization of activities
- Rigorous engineering analysis



Program Growth Opportunities

OPPORTUNITY:

Expand program scope to demonstrate a series of product enhancements to address additional market opportunities.

ADDED ACTIVITIES:

- Opportunistic Fuel Ready
- Multi-Source Power Electronics
- True Autonomous Control
- Advanced Turbo Equipment Materials
- Advanced Recuperators
- Rigorous Lab & Field Evaluation

SCHEDULE:

Increase Timeline by 2 years to Accommodate Additional Scope

Expanded Program Address More Technology Issues, Risks & a Larger Market Potential